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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

February 1, 2000

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th St., S.W.
Washington, DC 20554

Re: ***Ex Parte* Notification**
ET Docket No. 98-153
Ultra-Wideband

Dear Ms. Salas:

This is to note that on January 31, 2000, the attached written ex parte presentation was sent via email to Mr. Julius Knapp, Chief of the Policy and Rules Division of the Office of Engineering and Technology and to Mr. John Reed, Senior Engineer of the Technical Rules Branch of the Division.

Should any questions arise concerning this matter, please contact me.

Respectfully,

David E. Hilliard

David E. Hilliard
Counsel for Time Domain Corporation

cc: Messrs. Knapp and Reed (w/enclosure)

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List ABCDE

Paul Withington
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01/31/00 09:26 AM

To: JKNAPP@fcc.gov, jreed@fcc.gov, jinglis@erols.com

cc: David Hilliard <dhilliard@wrf.com>

Subject: Controlling UWB EMI

Gentlemen:

I read this article in the Electronic Engineering Times January 17th edition. You don't need to read the whole article to understand what it says. All you need to do is read the title of the article and then look at the illustration.

"Intentional" time modulation of clock edges, it is clear, has "unintentional" consequences.

Best wishes,
Paul W.

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Spread spectrum reduces EMI problem

By Chris Arcus, Design Manager, Pericom Semiconductor Corp., San Jose, Calif.
EE Times
(01/18/00, 10:14 a.m. EST)

Electromagnetic interference is increasing as a result of higher clock speeds in today's PCs and workstations. This radiation, mainly produced by fundamental and low-order harmonics, unfortunately coincides and interferes with many popular radio FM bands. It has forced the regulatory agencies to place limits on electromagnetic radiation produced by PCs and any electronic instrument that might use clocks and generate emissions.

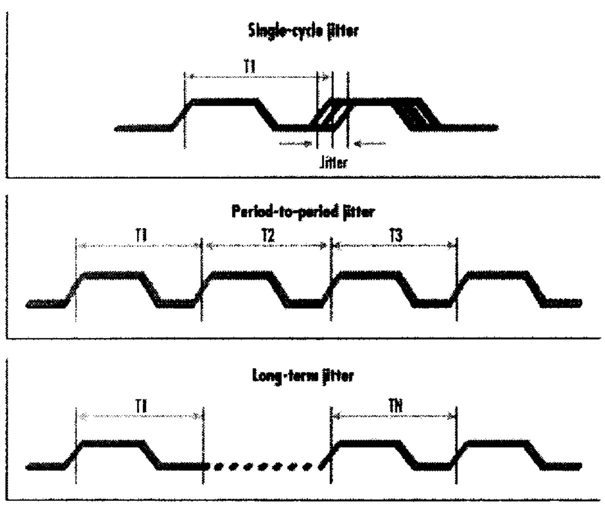
Almost any electrical transitions with sharp edges such as clocks, data, address and control produce electromagnetic radiation. As performance requirements increase, clock speeds have also increased. The transition edge, or the slew rate, has become faster and faster as the need for meeting setup and hold time has become harder. Setup is the time needed for a data pulse to be stable before the rising edge of the clock; hold time is the time for the data pulse to remain stable after the edge of the clock.

Clocks are no longer fed to only one or two devices on the printed-circuit board. Rather, they are being distributed all over the board. Also, increased memory requirements and other loads on the clock lines have significantly contributed to electromagnetic radiation. Electromagnetic interference (EMI) is linearly proportional to current, the area of the current loop and the square of frequency. EMI is defined as EMI = kIAf2 where I is the current, A is the loop area, f is the frequency and k is the constant depending on the circuit board's materials and other factors.

There are two types of EMI radiation: differential mode and common mode. The differential mode is caused by current loops formed between traces and the ground plane on PC add-in cards and motherboards, loops that act as antennas and radiate EMI that may exceed the FCC limits. Common mode is caused by localized ground noise injected into the PC's I/O traces and cable. Since these cables and traces are long, they act as antennas.

In the past shielding was the most prevalent method used to decrease EMI, though in some cases it was not an option. Issues like these have motivated today's designers to find more viable and effective methods to reduce radiation. One powerful method is called spread spectrum.

Spread spectrum modulates the signal and spreads the energy over a wider frequency range. In reality it is a controlled and careful modulation of the clock signal in a way that does not contribute significantly to jitter. It has been successfully shown that by using spread spectrum, radiation is lowered from 7 to 20 dB, depending on the degree of the modulation.



Clock jitter, the random variation in the period of a clock signal, needs to be considered at several scales. Single-cycle jitter is the irregularity found in each clock cycle. Once that is controlled, jitter can emerge as random variations in successive clock cycles. Ultimately, the variation over longer trains of clock pulses must also be monitored and controlled.

Spread spectrum is mainly applied to square wave signals. These signals include both fundamental frequency and odd multiples of the fundamental frequency, with the energy contained in both the fundamental and the harmonics. The harmonic energy decreases with order since the spectral density rolls off at a rate that is inversely proportional to the frequency.

Since most clocks do not have 50 percent duty cycle, the magnitude of harmonics is higher. In addition, the spectrum is related to the Fourier transform of the signal, which displays the signals in the frequency domain that is displaying the frequency content. For example, a sinusoidal signal that is only at a single frequency will appear as a vertical spike at that frequency in the frequency domain.

The most severe radiation involves the fundamental-the third and fifth harmonic of the clock frequency. Distributing the fundamental energy over a tightly controlled range, as in spread spectrum, also distributes the harmonic energy over a wider range. This is because the bandwidth of the nth harmonic is n times the bandwidth of the fundamental. The spread-spectrum method must be controlled and slow compared to clock rate to guarantee that the change in the clock rate is transparent to the system. Both cycle-to-cycle and peak-to-peak jitter must remain within the system's specifications.

Essentially, spread spectrum is a modulation method where the modulation is measured as a percentage. For example, a 0.5 percent modulation means that a 100-MHz clock is modulated between 99.5 and 100.5 MHz. This is called a center 0.5 percent modulation (delta), since the 100-MHz fundamental frequency remains the center frequency.

Another important factor is the modulation frequency, which is usually in the kilohertz range. This is basically a measure of the rate at which the frequency is swept between 99.5 and 100.5. The linear sweep is predictable and most prevalent.

The spread-spectrum method must guarantee also that the minimum clock period is not violated. The clock is usually swept between 99.5 and 100 MHz to avoid exceeding the maximum frequency of the system, a method called downspreading. In this case the clock frequency deviation is measured as a negative percentage; here the spread is -0.5 percent (delta).

Spread spectrum has mainly been applied to system clocks. The clock specifications for today's 400-MHz PCs call for specific reductions in electromagnetic radiation due to the clock alone. Pericom clocks with spread-spectrum capability, such as PI6C104 for desktop applications and PI6C103 and 102 for mobile applications, allow more margins for EMI emission compliance in the overall system. All Pericom desktop and mobile PC clocks possess spread-spectrum EMI reduction capability. The PI6C104's spread-spectrum capability provides modulation on the CPU and PCI clocks only. Fixed clocks such as REF and others (24 and 48 MHz) are not modulated.

With the use of the I2C control method, Pericom's PC clocks allow several types of modulation. For example, the PI6C104 allows a delta of 0.5, 0.9, 1, -1, -0.5 and 0.25 percent, plus no modulation at all (spread spectrum is off). Modulation frequency is set at 60 kHz. The spread-spectrum modulation introduces an insignificant amount of jitter to the clock at modulation frequencies such as 30 to 60 kHz.

To combat EMI, designers have also adhered to a series of guides and methods. We highly recommend that solid ground and power planes be used in the design; partitioned ground and power planes must be avoided. These ground and power partitions may create complex current loops. In this case, the larger the current loops the higher the magnitude of radiation. Routing any channel lines, especially clocks, over a segmented ground plane must be avoided.

Place the clock drivers near the center of the circuit board rather than at the periphery. Placing the clock drivers at the periphery increases the magnetic dipole moments. For clock traces that are routed on the surface plane, to further reduce EMI it is better to route parallel ground traces on either side of the clock trace. However, it is even better to place the clock traces in the layer in between ground and Vcc plane . Use 4- to 8-mil traces for clock signals, since narrow signal traces tend to increase high-frequency damping and reduce capacitate coupling between traces. In general, right angles or T crosses should be avoided because right angles increase trace capacitance and also add an impedance discontinuity that effects signal degradation.

Impedance must be matched as closely as possible-in most cases impedance mismatches cause emissions, and signal integrity depends mainly on impedance matching. Do not run long clock traces parallel to each other because they effect crosstalk that contributes to EMI. It is a good idea to make sure that the spacing between traces is at least equal to the trace width.

If you are designing graphics memory subsystems, make sure clock traces are placed at least 2.5 inches away from any PC I/O connector. This includes parallel ports, serial ports, keyboard connector, monitor connector, etc. This meth-od should minimize the common-mode radiation, which is reduced by placing ground isolation trenches around the I/O connector. To suppress high-frequency common-mode radiation, we suggest ferrites with appropriate impedance characteristics. Since the impedance of the ferrites varies with frequency, at high frequency ferrites behave more like a resistor than an inductor and ferrite resistive losses can be used to fight radiation.

Using Vdd decoupling capacitors for clock sources (whether external or internal) should help reduce the EMI. Placement of decoupling caps is very important to reduce emissions from the package of the clock source. All capacitors should be placed within 20 mils of Vdd pins. Decoupling cap values are based on the resonance frequency of the capacitor. Capacitors in the 100-pF range are appropriate for the higher frequencies of the clock generator.

Reduce the length of high-frequency trace as well as the area of current loops. RC filters at the clock source are placed to control the rise and fall times. Slower rise and fall times result in lower emitted frequencies.

The power supply pins for the clock should be next to ground pins. Minimize power supply loops. By keeping the power and ground leads parallel and adjacent to each other significant reductions in package EMI can be realized.

When the source of signal noise cannot be eliminated, filtering is recommended as the last resort. EMI filters and ferrite beads are commonly available filters. Ferrite beads add inductance to suppress high frequency.

Bidirectional benefits

EMI filters are commercially available to eliminate high-frequency noise in power lines. They not only stop the noise from entering the system but they stop the noise manufactured by the system from affecting other parts of the bigger system, an effect that is called bidirectional. A combination of inductors and capacitors make up the EMI filters. The impedance of the node that requires the EMI filter determines this configuration of capacitors and inductors. A high-impedance node requires a capacitor and a low-impedance node requires an inductor.

EMI filters can also be in configurations such as feedthrough capacitors, L circuits, PI circuits and T circuits. The only component of a feedthrough capacitor is a capacitor. Feedthrough capacitors are a good choice when the impedance connected to the filter is high.

In addition to clocks, high-speed devices generate more high-frequency noise because of shorter transition times that have more energy in the high-frequency range. Overall, the spread spectrum method has allowed system performance to increase without compromising EMI. Spread spectrum can expedite time-to-market of products that may create interference and reduce packaging and shielding costs. At the same time designers should use all the available methods and guides to reduce EMI.